



# MP3314A

## 6-Channel, 80mA, 50V, Boost WLED Driver with I<sup>2</sup>C Interface

### DESCRIPTION

The MP3314A is a boost converter with 6-channel current sources designed to drive WLED arrays for LCD panels in virtual reality (VR) backlighting applications.

The MP3314A uses peak current mode and pulse-width modulation (PWM) control to maintain boost converter regulation. The integrated 6 channels of the LED current source support a maximum current of 80mA per channel.

The MP3314A provides two PWM input signals (PWM1 and PWM2) to control the brightness of LED channel 1 to channel 3 and LED channel 4 to channel 6, respectively.

The MP3314A employs a standard I<sup>2</sup>C digital interface to set the LED current, switching frequency ( $f_{sw}$ ), frequency spread spectrum (FSS), and various protection thresholds.

The MP3314A supports a configurable switching slope and the FSS function to improve EMI performance.

The MP3314A features high efficiency due to low-headroom voltage for LED regulation and the switching MOSFET's small on resistance ( $R_{DS(ON)}$ ).

For system reliability, the MP3314A integrates rich protections, including LED open protection, LED short protection, over-current protection (OCP), over-voltage protection (OVP), and over-temperature protection.

The MP3314A is available in a WLCSP-20 (1.7mmx2.45mm) package.

### FEATURES

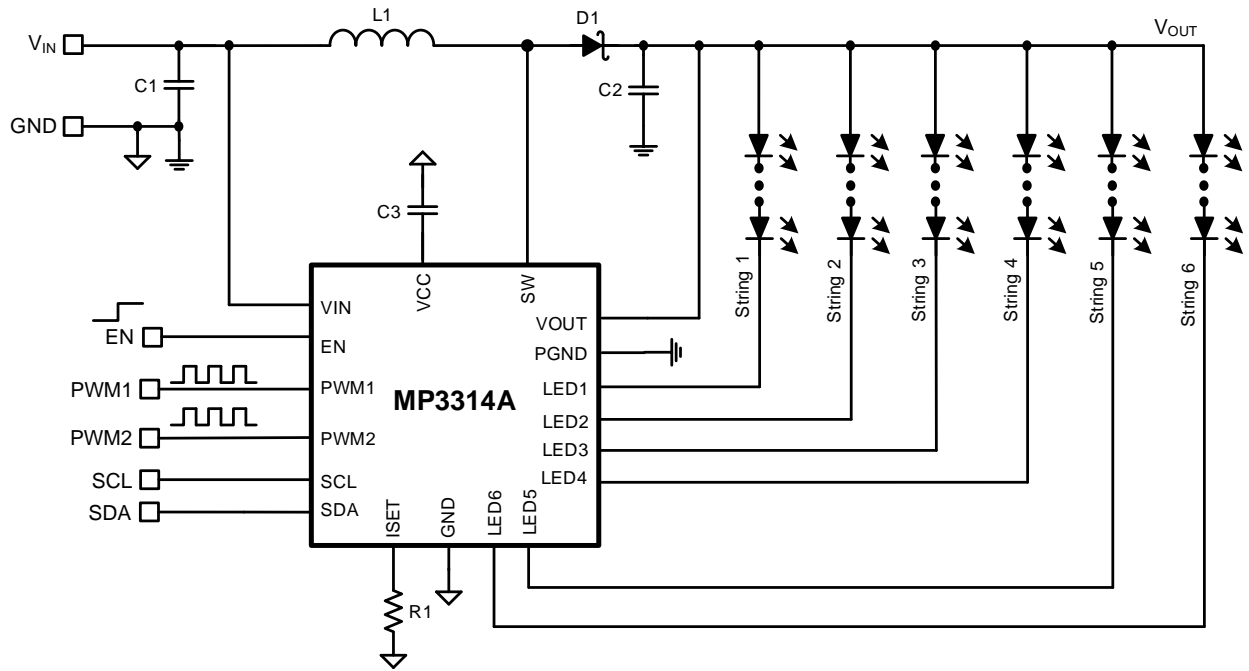
- 6 Channels with Maximum 80mA/Channel
- Integrated 50V, 130m $\Omega$ , On Resistance ( $R_{DS(ON)}$ ) Low-Side MOSFET (LS-FET)
- 3V to 30V Input Voltage ( $V_{IN}$ ) Range
- Up to 43V of Output Voltage ( $V_{OUT}$ )
- 187.5mV LED Regulation Voltage at 20mA
- 2%  $I_{LED}$  Accuracy, <3% LED Current ( $I_{LED}$ ) Matching at 20mA
- Selectable Switching Frequency ( $f_{sw}$ ): 312kHz, 625kHz, or 1250kHz
- I<sup>2</sup>C Brightness Control
- Manual Mode and Direct Pulse-Width Modulation (PWM) Dimming
- PWM1 and PWM2 Input Signals to Control Channel 1 to Channel 3 and Channel 4 to Channel 6, Respectively
- Configurable Switching Slope and Frequency Spread Spectrum (FSS) Function to Improve EMI
- One-Time Programmable (OTP) Memory for Customizable Default Register Values
- LED Open/Short Protection
- Over-Temperature Protection
- Over-Current Protection (OCP), Inductor, or Diode Short Protection
- Available in a WLCSP-20 (1.7mmx2.45mm) Package

### APPLICATIONS

- Virtual Reality (VR) Displays
- LCD Panel Backlighting

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### TYPICAL APPLICATION



### ORDERING INFORMATION

| Part Number | Package                 | Top Marking | MSL Rating |
|-------------|-------------------------|-------------|------------|
| MP3314AGC*  | WLCSP-20 (1.7mmx2.45mm) | See Below   | 1          |

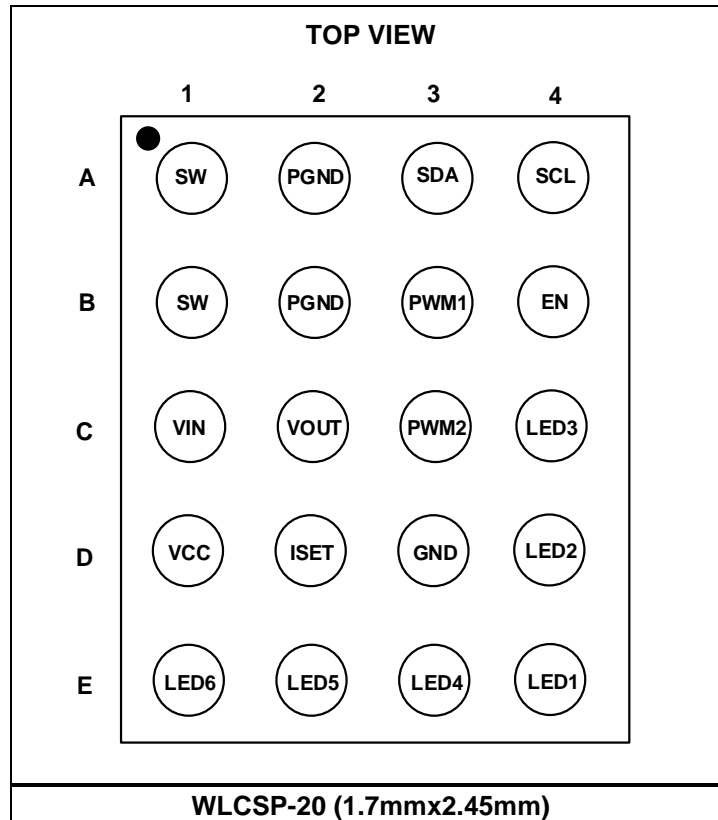
\* For Tape & Reel, add suffix -Z (e.g. MP3314AGC-Z).

### TOP MARKING

PEY  
LLL

PE: Product code  
Y: Year code  
LLL: Lot number

### PACKAGE REFERENCE



## PIN FUNCTIONS

| Pin #  | Name | Description   |
|--------|------|---|
| A1, B1 | SW   | <b>Drain for the internal low-side MOSFET (LS-FET) switch.</b>  |
| A2, B2 | PGND | <b>Power ground.</b>  |
| A3     | SDA  | <b>I<sup>2</sup>C interface data input/output.</b>  |
| A4     | SCL  | <b>I<sup>2</sup>C interface clock input.</b>  |
| B4     | EN   | <b>IC enable.</b> Pull the EN pin high to enable the IC; pull EN low to force the IC to enter shutdown mode. A nearby RC filter is required for this pin.                     |
| B3     | PWM1 | <b>External pulse-width modulation (PWM) signal input 1.</b> Apply a 50Hz to 5kHz PWM signal on the PWM1 pin for the brightness control of channel 1 to channel 3.            |
| D3     | GND  | <b>Chip ground.</b>   |
| E4     | LED1 | <b>LED string 1 current input.</b> Connect LED string 1's cathode to the LED1 pin.  |
| D4     | LED2 | <b>LED string 2 current input.</b> Connect LED string 2's cathode to the LED2 pin.  |
| C4     | LED3 | <b>LED string 3 current input.</b> Connect LED string 3's cathode to the LED3 pin.  |
| E3     | LED4 | <b>LED string 4 current input.</b> Connect LED string 4's cathode to the LED4 pin.  |
| E2     | LED5 | <b>LED string 5 current input.</b> Connect LED string 5's cathode to the LED5 pin.  |
| E1     | LED6 | <b>LED string 6 current input.</b> Connect LED string 6's cathode to the LED6 pin.  |
| D1     | VCC  | <b>5V low-dropout (LDO) output.</b> The VCC pin provides power for the internal logic and gate driver. Place a ceramic capacitor as close to VCC as possible to reduce noise. |
| C2     | VOUT | <b>Output voltage detection.</b> Connect the power diode's cathode to the VOUT pin.   |
| C3     | PWM2 | <b>External PWM signal input 2.</b> Apply a 50Hz to 5kHz PWM signal on the PWM2 pin for the brightness control of channel 4 to channel 6.                                     |
| C1     | VIN  | <b>Power supply input.</b> A nearby bypass capacitor is required for the VIN pin.   |
| D2     | ISET | <b>LED current setting.</b> Connect a current-setting resistor between the ISET and GND pins to configure the current in each LED string.                                     |

### ABSOLUTE MAXIMUM RATINGS <sup>(1)</sup>

|  |                 |
|--|-----------------|
| $V_{SW}, V_{LEDx}, V_{OUT}$ .....  | -0.3V to +50V   |
| $V_{IN}$ .....   | -0.3V to +32V   |
| All other pins.....  | -0.3V to +5.3V  |
| Junction temperature ( $T_J$ ) .....                                     | 150°C           |
| Lead temperature .....   | 260°C           |
| Storage temperature.....   | -65°C to +150°C |
| Continuous power dissipation ( $T_A = 25^\circ\text{C}$ ) <sup>(2)</sup> |                 |
| WLCSP-20 (1.7mmx2.45mm) .....  | 2.5W            |

### ESD Ratings

|                                  |                |
|----------------------------------|----------------|
| Human body model (HBM) .....     | ±2kV           |
| Charged-device model (CDM) ..... |                |
| .....                            | +1.5kV/-1.25kV |

### Recommended Operating Conditions <sup>(3)</sup>

|  |                 |
|--|-----------------|
| Supply voltage ( $V_{IN}$ ) .....      | 3V to 30V       |
| Operating junction temp ( $T_J$ ) .... | -40°C to +125°C |

### Thermal Resistance <sup>(4)</sup> $\theta_{JA} \theta_{JC}$

|                              |                     |
|------------------------------|---------------------|
| WLCSP-20 (1.7mmx2.45mm)..... |                     |
| .....                        | 50.....0.5.....°C/W |

#### Notes:

- 1) Exceeding these ratings may damage the device.
- 2) The maximum allowable power dissipation is a function of the maximum junction temperature,  $T_J$  (MAX), the junction-to-ambient thermal resistance,  $\theta_{JA}$ , and the ambient temperature,  $T_A$ . The maximum allowable continuous power dissipation at any ambient temperature is calculated by  $P_D$  (MAX) =  $(T_J$  (MAX) -  $T_A$ ) /  $\theta_{JA}$ . Exceeding the maximum allowable power dissipation produces an excessive die temperature, causing the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
- 3) The device is not guaranteed to function outside of its operating conditions.
- 4) Measured on a JESD51-7, 4-layer PCB.

## ELECTRICAL CHARACTERISTICS

$V_{IN} = 7.6V$ ,  $V_{EN} = 2V$ ,  $T_J = 25^{\circ}C$ , unless otherwise noted.

| Parameter   | Symbol            | Condition   | Min  | Typ  | Max  | Units      |
|---|-------------------|---|------|------|------|------------|
| <b>Input Voltage Supply</b>                       |                   |   |      |      |      |            |
| Operating input voltage                           | $V_{IN}$          |   | 3    |      | 30   | V          |
| Supply current                                    | $I_{STANDBY}$     | LDO enabled, boost disabled, $-30^{\circ}C$ to $+85^{\circ}C$ |      | 1.6  | 1.8  | mA         |
|   | $I_{NORMAL}$      | LDO enabled, boost enabled, no load                           |      | 3    | 3.4  | mA         |
| Shutdown supply current                           | $I_{ST}$          | $V_{EN} = 0V$   |      |      | 1    | $\mu A$    |
| Input under-voltage lockout (UVLO) threshold      | $V_{IN\_UVLO}$    | Rising edge   | 2.3  | 2.5  | 2.7  | V          |
| Input UVLO hysteresis                             |                   |   |      | 125  |      | mV         |
| Low-dropout (LDO) output voltage                  | $V_{CC}$          | $V_{EN} = 2V$ , $6V < V_{IN} < 30V$ , $0mA < I_{VCC} < 10mA$  | 4.5  | 5    | 5.5  | V          |
| EN on threshold                                   | $V_{EN\_ON}$      | $V_{EN}$ rising   | 1.2  |      |      | V          |
| EN off threshold                                  | $V_{EN\_OFF}$     | $V_{EN}$ falling  |      |      | 0.4  | V          |
| EN pull-down resistor                             | $R_{EN}$          |   |      | 1000 |      | k $\Omega$ |
| <b>Step-Up Converter</b>                          |                   |   |      |      |      |            |
| Low-side MOSFET (LS-FET) on resistance            | $R_{DS(ON)\_LS}$  | $V_{IN} = 3.6V$   |      | 130  |      | m $\Omega$ |
| SW leakage current                                | $I_{SW\_LK}$      | $V_{SW} = 50V$  |      |      | 1    | $\mu A$    |
| Switching frequency                               | $f_{SW}$          | FSW (0Ah, [bits[5:4]] = 10b)                                  | 1200 | 1250 | 1300 | kHz        |
|   |                   | FSW (0Ah, [bits[5:4]] = 01b)                                  | 610  | 645  | 680  | kHz        |
| Maximum duty cycle                                | $D_{MAX}$         | FSW (0Ah, [bits[5:4]] = 10b)                                  | 89   |      |      | %          |
|   |                   | FSW (0Ah, [bits[5:4]] = 01b)                                  | 90   |      |      | %          |
| Cycle-by-cycle current limit                      | $I_{SW\_LIMIT}$   | ILIM (02h, bits[5:3]) = 000b                                  | 0.35 | 0.45 | 0.55 | A          |
|   |                   | ILIM (02h, bits[5:3]) = 101b                                  |      | 1.2  |      | A          |
| Latch off current limit                           | $I_{CL}$          | ILIM (02h, bits[5:3]) = 101b                                  | 2.3  | 2.9  | 3.5  | A          |
| Minimum turn on time                              | $t_{MIN\_ON}$     |   |      | 90   |      | ns         |
| <b>Dimming</b>                                    |                   |   |      |      |      |            |
| Pulse-width modulation (PWM) input high threshold | $V_{PWM\_HI}$     | $V_{PWM}$ rising  | 1.2  |      |      | V          |
| PWM input low threshold                           | $V_{PWM\_LO}$     | $V_{PWM}$ falling   |      |      | 0.4  | V          |
| PWM pull-down resistor                            | $R_{PWM}$         |   |      | 1000 |      | k $\Omega$ |
| Minimum on/off time                               | $t_{MIN\_ON/OFF}$ |   |      | 1    |      | $\mu s$    |
| PWM1 input low time for standby mode              | $t_{STANDBY}$     |   | 50   | 58   | 66   | ms         |

**ELECTRICAL CHARACTERISTICS (continued)**
**V<sub>IN</sub> = 7.6V, V<sub>EN</sub> = 2V, T<sub>J</sub> = 25°C, unless otherwise noted.**

| Parameter  | Symbol               | Condition   | Min  | Typ  | Max  | Units |
|--|----------------------|---|------|------|------|-------|
| <b>LED Current Regulation</b>                            |                      |   |      |      |      |       |
| Current matching <sup>(6)</sup>                          |                      | V <sub>LEDx</sub> = 187.5mV, I <sub>LED</sub> = 20mA  |      |      | 3    | %     |
| Full-scale current                                       |                      | I <sub>LED</sub> , bits[11:0] = FFFh, I <sub>MAX</sub> (07h, bits[6:4]) = 111b, R <sub>ISSET</sub> = 40kΩ | 49   | 50.5 | 52   | mA    |
|  |                      | I <sub>LED</sub> , bits[11:0] = FFFh, I <sub>MAX</sub> (07h, bits[6:4]) = 011b, R <sub>ISSET</sub> = 40kΩ | 19.6 | 20   | 20.4 | mA    |
| Maximum LED current                                      | I <sub>LED_MAX</sub> | R <sub>ISSET</sub> = 25kΩ, I <sub>MAX</sub> (07h, bits[6:4]) = 111b                                       |      | 80   |      | mA    |
| LEDx leakage current                                     | I <sub>LED_LKG</sub> | V <sub>OUT</sub> = 50V  |      |      | 1    | μA    |
| <b>Protection</b>  |                      |   |      |      |      |       |
| Over-voltage protection (OVP) threshold                  | V <sub>OVP</sub>     | Rising edge, OVP (04h, bits[5:3]) = 111b  |      | 43   |      | V     |
|  |                      | Rising edge, OVP (04h, bits[5:3]) = 010b  |      | 21   |      | V     |
| OVP UVLO threshold                                       | V <sub>OVP_UV</sub>  | The step-up converter fails   |      | 1    |      | V     |
| LEDx over-voltage (OV) threshold                         | V <sub>LEDx_OV</sub> | LEDS (0Bh, bits[3:2]) = 01b   |      | 5    |      | V     |
| LEDx OV fault timer                                      |                      |   |      | 1.8  |      | ms    |
| LEDx UVLO threshold                                      | V <sub>LEDx_UV</sub> |   |      | 80   |      | mV    |
| Thermal shutdown threshold                               | T <sub>ST</sub>      | Rising edge <sup>(5)</sup>  |      | 150  |      | °C    |
|  |                      | Hysteresis <sup>(5)</sup>   |      | 20   |      | °C    |
| <b>I<sup>2</sup>C Interface</b>                          |                      |   |      |      |      |       |
| Input logic low  | V <sub>IL</sub>      |   |      |      | 0.54 | V     |
| Input logic high   | V <sub>IH</sub>      |   | 1.5  |      |      | V     |
| Output logic low <sup>(5)</sup>                          | V <sub>OL</sub>      | I <sub>LOAD</sub> = 3mA   |      |      | 0.4  | V     |
| SCL clock frequency <sup>(5)</sup>                       | f <sub>SCL</sub>     |   | 10   |      | 1000 | kHz   |
| Bus free time <sup>(5)</sup>                             | t <sub>BUF</sub>     | Between the stop and start command  | 0.5  |      |      | μs    |
| Holding time after repeated start command <sup>(5)</sup> | t <sub>HD_STA</sub>  | After this period, the first clock is generated   | 0.26 |      |      | μs    |
| Repeated start command set-up time <sup>(5)</sup>        | t <sub>SU_STA</sub>  |   | 0.26 |      |      | μs    |
| Stop condition set-up time <sup>(5)</sup>                | t <sub>SU_STO</sub>  |   | 0.26 |      |      | μs    |
| Data hold time <sup>(5)</sup>                            | t <sub>HD_DAT</sub>  |   | 0    |      |      | ns    |
| Data set-up time <sup>(5)</sup>                          | t <sub>SU_DAT</sub>  |   | 50   |      |      | ns    |
| Clock low timeout <sup>(5)</sup>                         | t <sub>TIMEOUT</sub> |   | 25   |      | 35   | ms    |
| Clock low time <sup>(5)</sup>                            | t <sub>LOW</sub>     |   | 0.5  |      |      | μs    |
| Clock high time <sup>(5)</sup>                           | t <sub>HIGH</sub>    |   | 0.26 |      | 50   | μs    |
| Clock/data falling time <sup>(5)</sup>                   | t <sub>F</sub>       |   |      |      | 120  | ns    |
| Clock/data rising time <sup>(5)</sup>                    | t <sub>R</sub>       |   |      |      | 120  | ns    |

**Notes:**

5) Not tested in production. Guaranteed by characterization.

6) Matching is defined as the difference between the maximum current and minimum current, divided by 2 times the average current.

### TIMING DIAGRAM

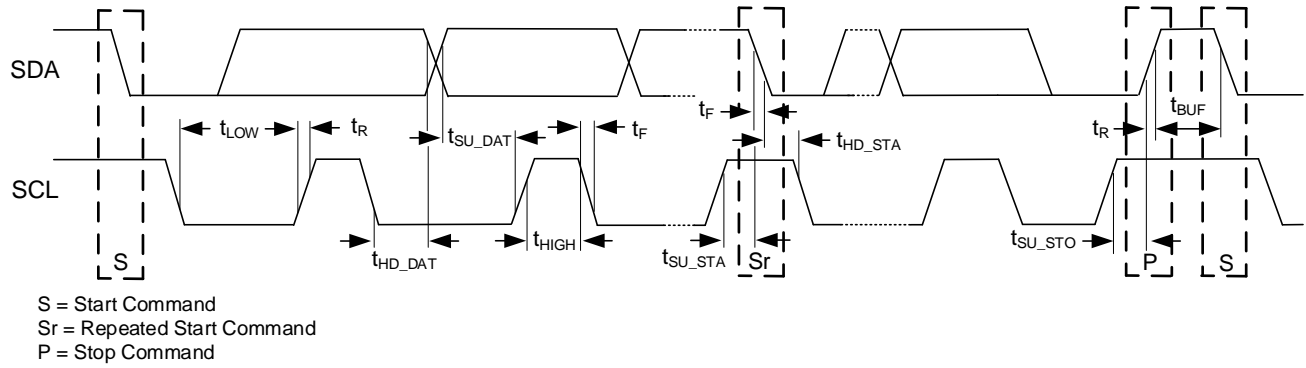
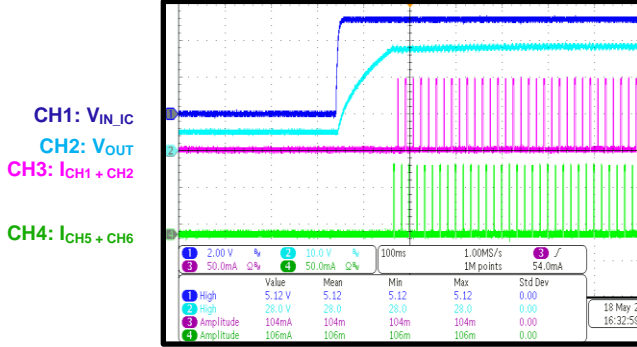


Figure 1: I<sup>2</sup>C-Compatible Interface Timing Diagram

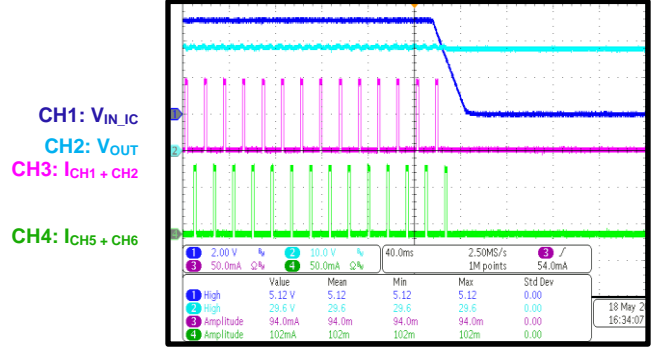
## TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN\_BOOST} = 2.5V$ ,  $V_{IN\_IC} = EN = 5V$ ,  $f_{PWM} = 60Hz$ , duty = 13%, LED = 4P8S,  $I_{SET} = 45mA/Ch$ ,  $CL = 0.75A$ ,  
 $f_{SW} = 625kHz$ ,  $L = 3.3\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

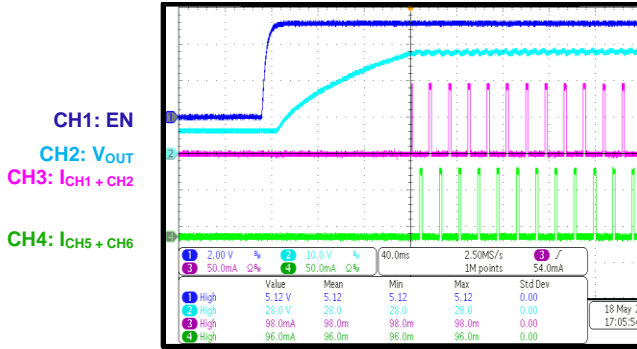
### V<sub>IN\_IC</sub> Start-Up



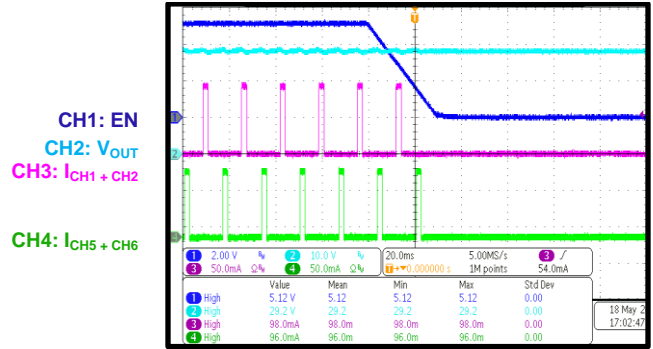
### V<sub>IN\_IC</sub> Shutdown



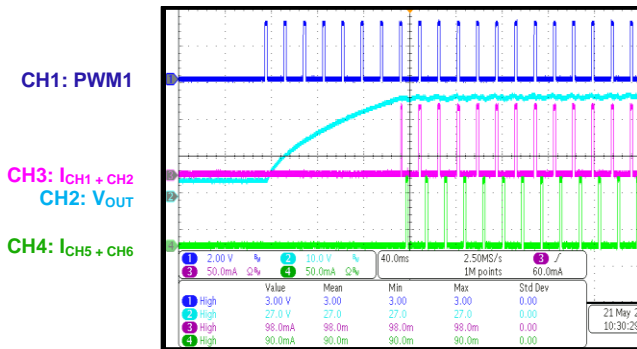
### Start-Up through EN



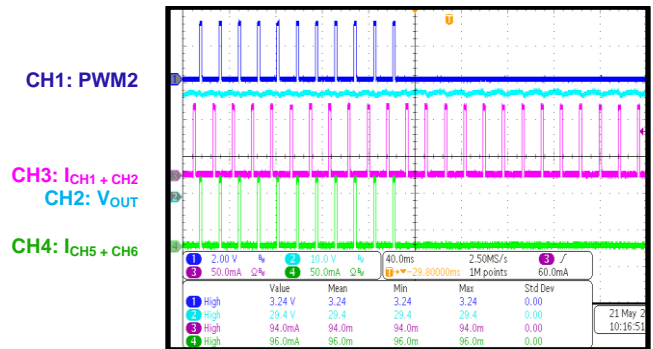
### Shutdown through EN



### Start-Up through PWM2, then Start-Up through PWM1

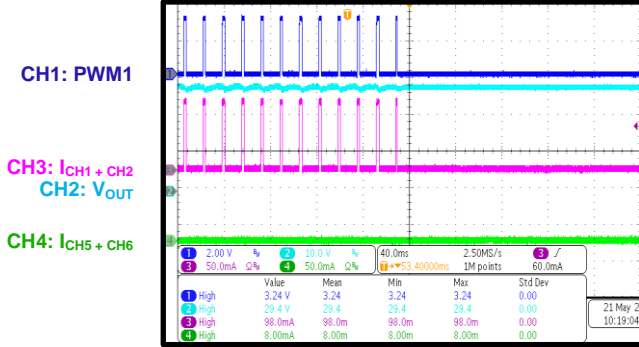


### Shutdown through PWM2 First

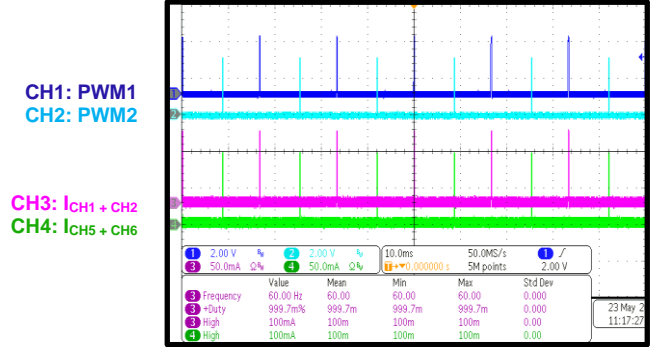


**TYPICAL PERFORMANCE CHARACTERISTICS (continued)**

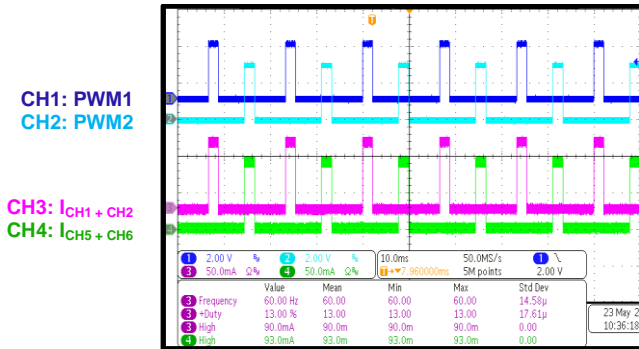
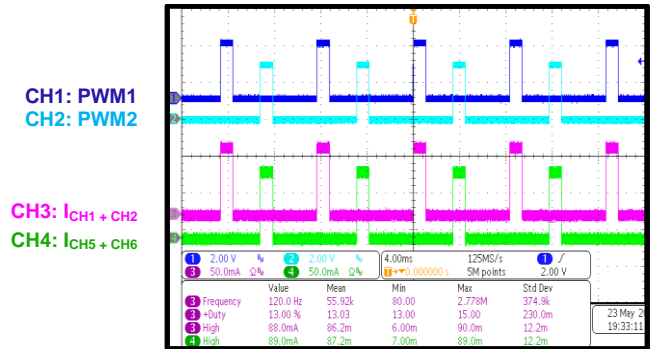
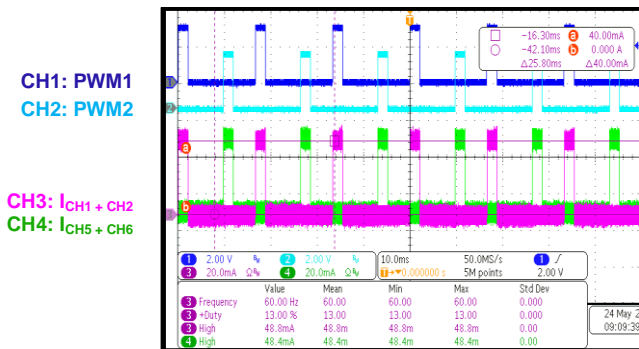
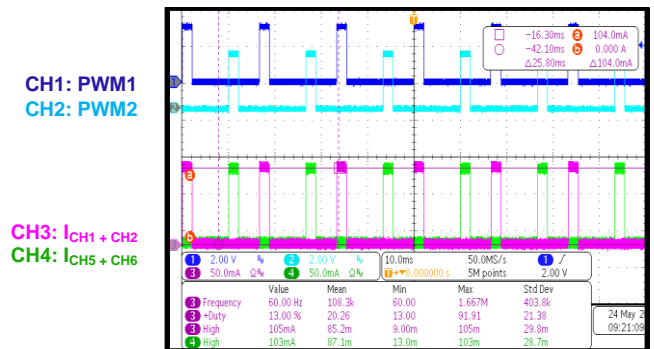
$V_{IN\_BOOST} = 2.5V$ ,  $V_{IN\_IC} = EN = 5V$ ,  $f_{PWM} = 60Hz$ , duty = 13%, LED = 4P8S,  $I_{SET} = 45mA/Ch$ ,  $CL = 0.75A$ ,  
 $f_{SW} = 625kHz$ ,  $L = 3.3\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

**Shutdown through PWM1 Second**

**Direct PWM Dimming**

Duty = 1%


**Direct PWM Dimming**

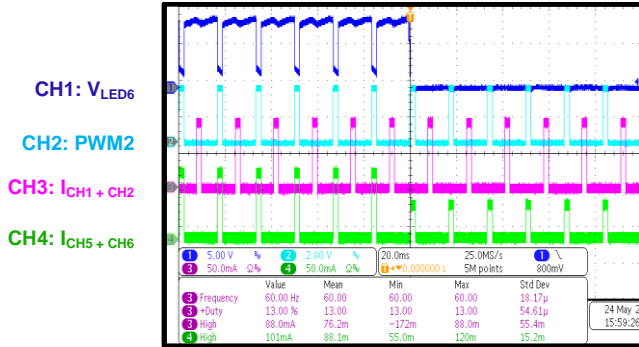
Duty = 13%


**Direct PWM Dimming**
 $f_{PWM} = 120Hz$ 

**Direct PWM Dimming**
 $I_{LED} = 20mA$ 

**Direct PWM Dimming**
 $I_{LED} = 50mA$ 


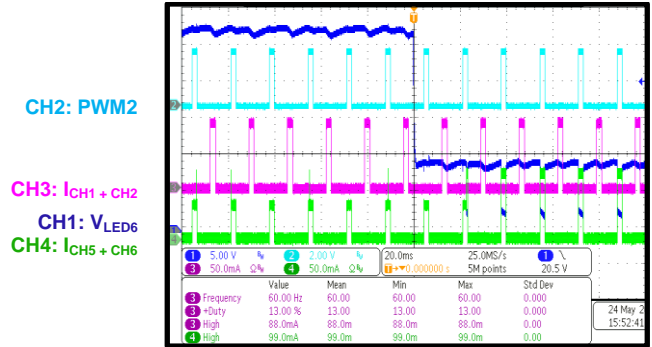
## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN\_BOOST} = 2.5V$ ,  $V_{IN\_IC} = EN = 5V$ ,  $f_{PWM} = 60Hz$ , duty = 13%, LED = 4P8S,  $I_{SET} = 45mA/Ch$ ,  $CL = 0.75A$ ,  $f_{SW} = 625kHz$ ,  $L = 3.3\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

### LED Open Protection Open LED string 6

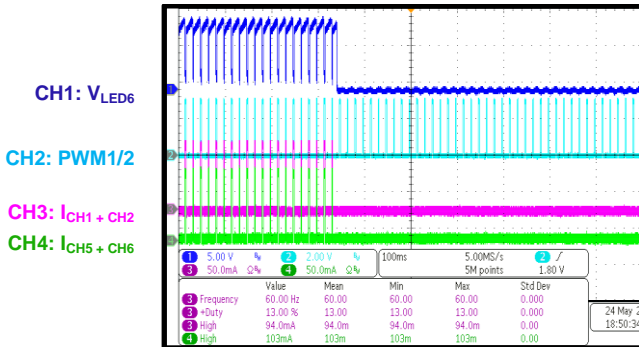


### LED Short Protection Short LED string 6



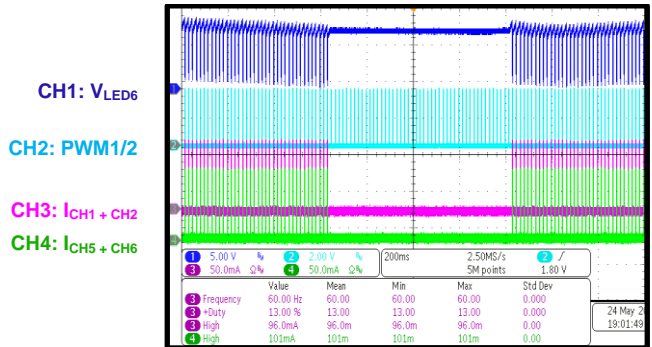
### Latch-Off Current-Limit Protection

Short diode during normal operation



### Over-Temperature Protection

Heat the IC manually, then recover



## FUNCTIONAL BLOCK DIAGRAM

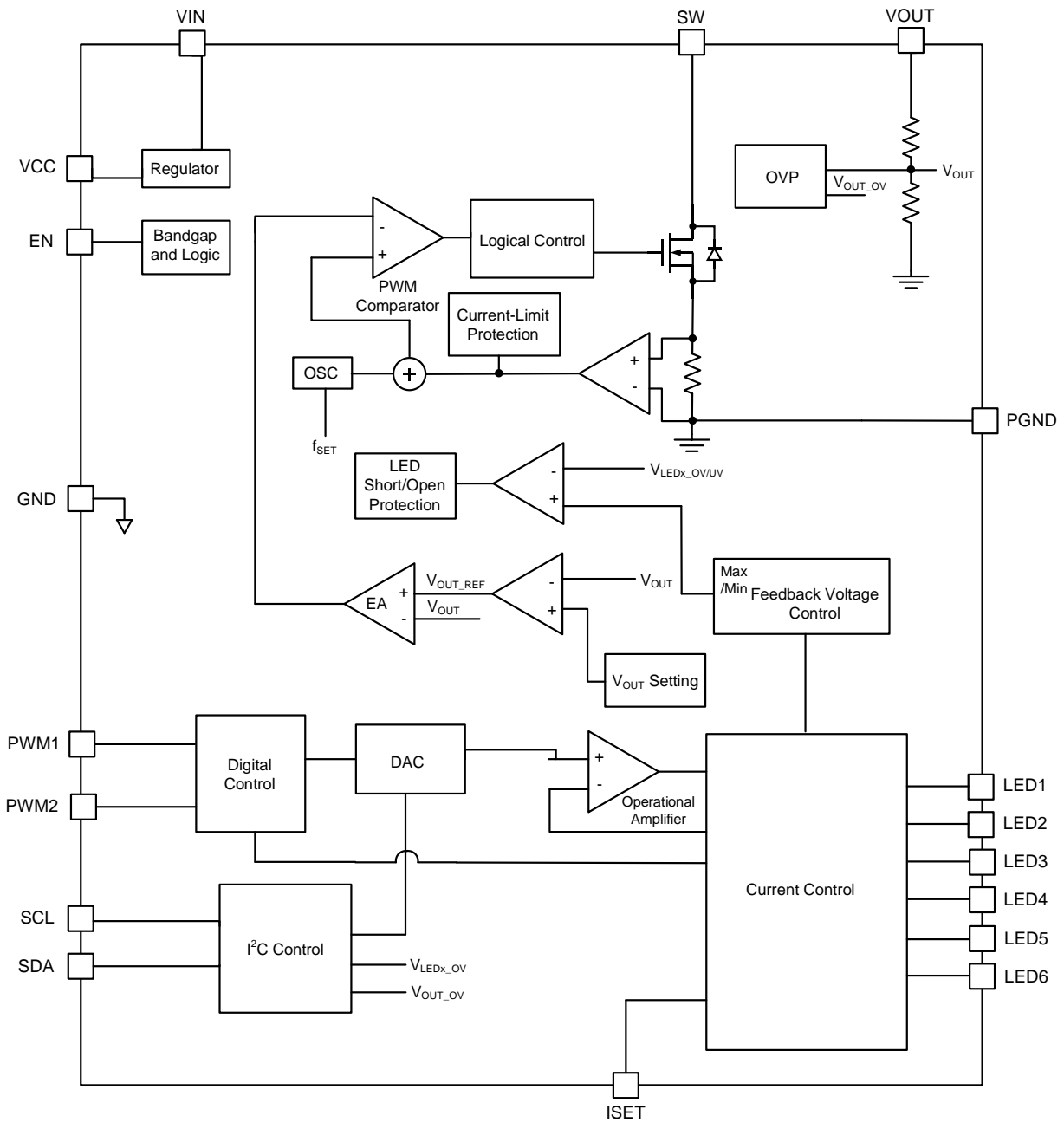


Figure 2: Functional Block Diagram

## OPERATION

The MP3314A is a fixed-frequency, peak current mode, step-up converter with up to 6 channels of regulated current sources to drive an array of white LEDs. The device integrates a low-side MOSFET (LS-FET) with a 50V rating, which supports a maximum 43V output voltage ( $V_{OUT}$ ).

### Internal Regulator

The MP3314A includes an internal linear regulator (VCC). When the input voltage ( $V_{IN}$ ) exceeds 6V and the EN pin is high, this regulator outputs a 5V power supply for the internal MOSFET gate driver and internal control circuitry.

When the boost input voltage ( $V_{IN\_BOOST}$ ) is below 3.5V, it is recommended to use an external 5V power supply to the VIN pin, which helps improve system efficiency.

### Internal Clock

The MP3314A provides a fixed 20MHz clock for the internal digital logic.

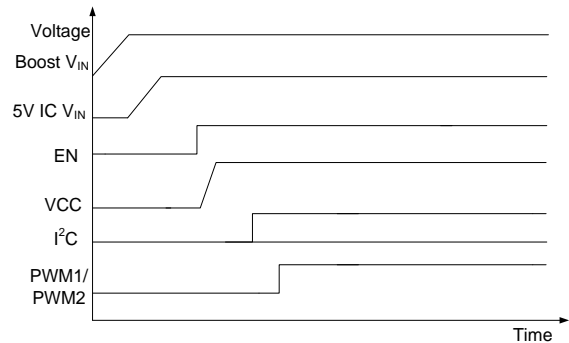
### Switching Frequency of the Boost Converter

The boost converter's switching frequency ( $f_{SW}$ ) can be set via FSW (0Ah, bits[5:4]).  $f_{SW}$  can be set to 312kHz, 625kHz, and 1250kHz.

### System Start-Up

When enabled, the MP3314A checks the topology connection. The IC monitors  $V_{OUT}$  to determine if the output is shorted to GND. If  $V_{OUT}$  is below 1V, the IC is disabled. Then the MP3314A continues to check other safety limits, such as LED open protection and over-voltage protection (OVP). If all protection tests pass, the IC begins boosting the step-up converter with an internal soft start (SS).

The MP3314A can start up properly regardless of the start-up sequence of VIN, PWM1, PWM2, and EN. Figure 3 shows the recommended start-up sequence to achieve a quick response.



**Figure 3: Recommended Start-Up Sequence**

The start-up sequence occurs in the following order:

1. Boost VIN start-up
2. IC VIN start-up
3. EN start-up, then wait for 2ms
4. Send the I<sup>2</sup>C data
5. Apply the external PWM1 and PWM2 signal. When PWM1 or PWM2 is disabled, the corresponding channels remain off.

If SBY\_PWM = 1b and PWM1 remains low for longer than 58ms, then the IC enters standby mode, and all blocks are disabled, except for the I<sup>2</sup>C.

### Step-Up Converter

The MP3314A uses peak current mode control to regulate  $V_{OUT}$ . At the beginning of each switching cycle, the internal clock turns on the low-side N-channel MOSFET. In normal operation, the minimum turn-on time is about 90ns. A stabilizing ramp added to the current-sense amplifier's output prevents subharmonic oscillations for duty cycles exceeding 50%. This result is fed into the pulse-width modulation (PWM) comparator. When the summed voltage reaches  $V_{OUT}$  of the error amplifier (EA), the LS-FET turns off.

### Output Voltage Regulation in Manual Mode

For  $V_{OUT}$  regulation, the MP3314A only supports manual control mode, and the boost output voltage ( $V_{OUT\_BOOST}$ ) can be set directly via VO (0Eh, bits[7:0]).

### Pulse-Skip Mode (PSM)

During light-load operation, especially when  $V_{OUT} \approx V_{IN}$ , the converter runs in pulse-skip mode (PSM), where the MOSFET turns on for a minimum on time. In this mode, the device keeps the power switch off for several switching cycles to prevent  $V_{OUT}$  from exceeding the regulated voltage. When the device stops switching, the output capacitor ( $C_{OUT}$ ) discharges to power the LED string. The device begins switching until  $V_{OUT}$  must be boosted again.

### Direct Pulse-Width Modulation (PWM) Dimming

The MP3314A only supports direct PWM dimming mode. The frequency and duty of the LED current ( $I_{LED}$ ) directly follow the external PWM input signal. The  $I_{LED}$  amplitude is determined by IMAX (07h, bits[6:4]) and ILED, bits[11:0], which is the combination of ILED11:8 (07h, bits[3:0]) and ILED7:0 (06h, bits[7:0]), as well as the ISET resistor ( $R_{ISET}$ ) if it is enabled. PWM1 controls the channel 1 to channel 3 current, and PWM2 controls the channel 4 to channel 6 current, respectively.

### Frequency Spread Spectrum (FSS)

The MP3314A uses  $f_{SW}$  jitter to spread the  $f_{SW}$  spectrum, which reduces the spectrum spike around  $f_{SW}$  and its harmonic frequencies.

The frequency spread spectrum (FSS) range is selected by FSPR (0Bh, bit[4]), where:

- FSPR = 0b (default). The jitter range is 1/10 of  $f_{SW}$ .
- FSPR = 1b. The jitter range is 1/16 of  $f_{SW}$ .

The modulation frequency is selected by FSPMF (0Bh, bits[6:5]).

- FSPMF = 00b. The modulation frequency is 1/100 of  $f_{SW}$ .
- FSPMF = 01b. The modulation frequency is 1/150 of  $f_{SW}$ .
- FSPMF = 10b. The modulation frequency is 1/200 of  $f_{SW}$ .

- FSPMF = 11b (default). The function is disabled.

### Switching Slew Rate Setting

The MP3314A provides three types of driving capability for the internal MOSFET to improve the EMI performance. Set SRSW (0Ah, bits[7:6]) to configure the driving capability. EMI performance improves as driving capability decreases. However, there is a tradeoff between slow switching speed and efficiency.

### Unused LED Channel Setting

The MP3314A can detect an unused LED string automatically and remove it from the voltage control loop during start-up by setting the corresponding CHEN bits (or CHENx where x = 0, 1, 2, 3, 4, or 5) to 0.

### Protection

The MP3314A includes LED open protection, LED short protection, LEDx short to GND protection, over-current protection (OCP), and thermal protection. Once any of these protections are triggered, the corresponding fault bit is set to 1.

### Input Under-Voltage Lockout (UVLO) Protection

Input UVLO protection can be enabled or disabled via UVLO\_EN (08h, bit[5]). When UVLO\_EN = 0b, this function is disabled, and the status of FT\_UVLO (1Fh, bit[6]) is disregarded. If UVLO\_EN = 1b and  $V_{IN}$  is below the UVLO threshold, then the IC shuts down, and the I<sup>2</sup>C becomes inactive. If  $V_{IN}$  and EN remain valid, once  $V_{IN}$  recovers to exceed the UVLO threshold, then the IC recovers and the UVLO fault can be read to indicate a  $V_{IN}$  UVLO condition.

### LED Open Protection

LED open protection is achieved by detecting the voltage of the LED1 to LED6 pins.

In manual mode, if a LEDx pin voltage is below the LEDx UVLO threshold when dimming is on and the fault condition lasts for about 24ms, then LED open protection is triggered.

### **LED Short Protection**

The MP3314A monitors the LEDx pin voltages to determine if a LED short fault has occurred. If one or more LED strings are shorted, then the respective LEDx pins tolerate high voltage stress. If a LEDx pin voltage exceeds the protection threshold (set via LED<sub>S</sub> (0Bh, bits[3:2])), then an internal counter starts. If this fault condition lasts for 1.8ms, the fault LED string is marked off and disabled. Once a string is marked off, it is disconnected from the V<sub>OUT</sub> loop. Both LED open and short protection are recoverable.

LED short protection works only when a minimum of one LEDx voltage is regulated to the optimized voltage.

### **Cycle-by-Cycle Current Limit**

To prevent the external components from exceeding the current stress rating, the IC integrates cycle-by-cycle current-limit protection. The limit can be selected by ILIM (02h, bits[5:3]). When the current exceeds the current limit, the LS-FET turns off immediately until the next clock cycle begins.

### **Latch-Off Current-Limit Protection**

To avoid device damage caused by a large current (such as an inductor or diode short), the MP3314A uses a latch-off current-limit protection. When the current flowing through the

LS-FET reaches the latch-off current-limit threshold and lasts for five switching cycles, the protection is triggered, and the IC latches off.

### **Over-Temperature Protection**

To prevent the IC from operating at exceedingly high temperatures, thermal shutdown is implemented by detecting the silicon die temperature. Once the die temperature exceeds the upper threshold (T<sub>ST</sub>) and then drops below the lower threshold, the IC shuts down and resumes normal operation. Typically, the hysteresis is 20°C.

### **One-Time Programmable (OTP) Memory Mode**

The MP3314A can change the register's default values one time using the one-time programmable (OTP) memory function. MPS factory can write the customized default register values with different suffix codes.

### **I<sup>2</sup>C Chip Address**

The 7-bit most significant bit (MSB) device address is 0x28. After the start command, the I<sup>2</sup>C-compatible master sends a 7-bit address, followed by an eighth read (1) or write (0) bit (see Figure 4).

|   |   |   |   |   |   |   |     |
|---|---|---|---|---|---|---|-----|
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | R/W |
|---|---|---|---|---|---|---|-----|

**Figure 4: I<sup>2</sup>C Compatible Device Address**

**I<sup>2</sup>C REGISTER MAP** <sup>(7)</sup>

| Add | Name       | R/W | Default | D[7]     | D[6]    | D[5]    | D[4]     | D[3]     | D[2]    | D[1]    | D[0]     |          |
|-----|------------|-----|---------|----------|---------|---------|----------|----------|---------|---------|----------|----------|
| 02h | MODE_CTRL  | R/W | 9D      | ADAPTIVE | PWMDR   | ILIM    |          | RESERVED |         | R_EN    |          |          |
| 03h | SBY_CHEN   | R/W | 7F      | RESERVED | SBY_PWM | CHEN    |          |          |         |         |          |          |
| 04h | FUNC_SET_0 | R/W | 70      | RESERVED |         | OVP     |          | RESERVED |         |         |          |          |
| 06h | ILED_SET_0 | R/W | FF      | ILED7:0  |         |         |          |          |         |         |          |          |
| 07h | ILED_SET_1 | R/W | 3F      | RESERVED | IMAX    |         |          | ILED11:8 |         |         |          |          |
| 08h | FUNC_SET_1 | R/W | A7      | RESERVED |         | UVLO_EN | RESERVED |          | ISET_EN |         | RESERVED |          |
| 0Ah | SLEW_FREQ  | R/W | A0      | SRSW     |         | FSW     |          | RESERVED |         |         |          |          |
| 0Bh | FSS_LEDS   | R/W | 66      | RESERVED | FSPMF   |         | FSPR     |          | LEDS    |         | TCOMP    | RESERVED |
| 0Eh | VOUT_SET   | R/W | 32      | VO       |         |         |          |          |         |         |          |          |
| 1Dh | ID         | R   | 11      | ID       |         |         |          |          |         |         |          |          |
| 1Fh | FAULT      | R   | 00      | NC       | FT_UVLO | FT_LEDG | FT_OTP   |          | FT_OC_P | FT_OV_P | FT_LED0  | FT_LEDS  |

**Note:**

7) All registers can be written to the customized default values one time.

## I<sup>2</sup>C REGISTER DESCRIPTION

### MODE\_CTRL (02h)

The MODE\_CTRL command sets loop control mode, dimming mode, and the current limit of the boost circuit. It can also enable or disable the IC.

| Bits | Access | Bit Name | Default | Description   |
|------|--------|----------|---------|---|
| 7    | R/W    | ADAPTIVE | 1'b1    | Sets boost loop control mode.<br>1'b1: Adaptive control mode (invalid)<br>1'b0: Manual control mode (VR application; requires OTP)  |
| 6    | R/W    | PWMDR    | 1'b0    | Sets direct pulse-width modulation (PWM) dimming.<br>1'b0: Reserved<br>1'b1: Direct PWM dimming, where the LED current ( $I_{LED}$ ) follows the external PWM signal (VR application; requires OTP)   |
| 5:3  | R/W    | ILIM     | 3'b011  | Sets the cycle-by-cycle current limit.<br>3'b000: 0.45A<br>3'b001: 0.6A<br>3'b010: 0.75A<br>3'b011: 0.9A<br>3'b100: 1.05A<br>3'b101: 1.2A<br>3'b110: 1.35A<br>3'b111: 1.5A  |
| 2:1  | R      | RESERVED | N/A     | Reserved.   |
| 0    | R/W    | R_EN     | 1'b1    | Enables or disables the IC. This is the highest priority enable bit. When R_EN = 0, all blocks are disabled except for the I <sup>2</sup> C.<br>1'b0: Disabled<br>1'b1: Enabled<br><br>If an external PWM signal is used for brightness control, it can also be used to enable/disable the IC. SBY_PWM (03h, bit[6]) can configure this function. |

### SBY\_CHEN (03h)

The SBY\_CHEN command can enable or disable standby mode as well as 6 LED current sources.

| Bits | Access | Bit Name | Default   | Description   |
|------|--------|----------|-----------|---|
| 7    | R      | RESERVED | N/A       | Reserved.   |
| 6    | R/W    | SBY_PWM  | 1'b1      | Enables standby mode when the PWM1 pin is pulled low for a minimum of 58ms.<br>1'b0: Disabled<br>1'b1: Enabled  |
| 5:0  | R/W    | CHEN     | 6'b111111 | Enables the LED current source. These bits correspond to LED channel 1 to channel 6.<br>CHEN <sub>x</sub> = 1'b1: LED channel (x + 1) is enabled.<br>CHEN <sub>x</sub> = 1'b0: LED channel (x + 1) is disabled.<br><br>PWM1 controls channel 1 to channel 3.<br>PWM2 controls channel 4 to channel 6. |

**FUNC\_SET\_0 (04h)**

The FUNC\_SET\_0 command sets the brightness control source, over-voltage protection (OVP) threshold, and digital dithering function of the circuit.

| Bits | Access | Bit Name | Default | Description  |
|------|--------|----------|---------|--|
| 7:6  | R      | RESERVED | N/A     | Reserved.  |
| 5:3  | R/W    | OVP      | 3'b110  | Sets the output voltage (V <sub>OUT</sub> ) OVP threshold.<br>3'b010 = 21V<br>3'b011 = 25V<br>3'b100 = 30V<br>3'b101 = 34.5V<br>3'b110 = 39V<br>3'b111 = 43V |
| 2:0  | R      | RESERVED | N/A     | Reserved.  |

**ILED\_SET\_0 (06h)**

The ILED\_SET\_0 command sets the 8 least significant bits (LSB) of the 12-bit I<sub>LED</sub> amplitude register.

| Bits | Access | Bit Name | Default | Description   |
|------|--------|----------|---------|---|
| 7:0  | R/W    | ILED7:0  | 8'hFF   | Sets I <sub>LED</sub> for the 8LSB.<br>The 12-bit I <sub>LED</sub> amplitude register further scales the maximum I <sub>LED</sub> set by IMAX (07h, bits[6:4]). |

**ILED\_SET\_1 (07h)**

The ILED\_SET\_1 command sets the maximum I<sub>LED</sub> and the 4 most significant bits (MSB) of the 12-bit I<sub>LED</sub> amplitude register.

| Bits | Access | Bit Name | Default | Description   |
|------|--------|----------|---------|---|
| 7    | R      | RESERVED | N/A     | Reserved.   |
| 6:4  | R/W    | IMAX     | 3'b011  | Configures the maximum I <sub>LED</sub> .<br>3'b000: 5mA<br>3'b001: 10mA<br>3'b010: 15mA<br>3'b011: 20mA<br>3'b100: 23mA<br>3'b101: 25mA<br>3'b110: 30mA<br>3'b111: 50mA  |
| 3:0  | R/W    | ILED11:8 | 4'b1111 | Sets I <sub>LED</sub> for the 4MSB.<br>The 12-bit I <sub>LED</sub> amplitude register further scales the maximum I <sub>LED</sub> set by IMAX, bits[6:4] of this command. |

**FUNC\_SET\_1 (08h)**

The FUNC\_SET\_1 command sets the transfer point of mixed dimming, under-voltage lockout (UVLO), and enable/disable control of the external setting resistor.

| Bits | Access | Bit Name | Default | Description  |
|------|--------|----------|---------|--|
| 7:6  | R      | RESERVED | N/A     | Reserved.  |
| 5    | R/W    | UVLO_EN  | 1'b1    | Enables V <sub>IN</sub> UVLO.<br>1'b0: Disabled<br>1'b1: Enabled                         |
| 4:3  | R      | RESERVED | N/A     | Reserved.  |
| 2    | R/W    | ISET_EN  | 1'b1    | Enables the external I <sub>LED</sub> setting resistor.<br>1'b0: Disable<br>1'b1: Enable |
| 1:0  | R      | RESERVED | N/A     | Reserved.  |

**SLEW\_FREQ (0Ah)**

The SLEW\_FREQ command sets the boost switching slew rate, boost switching frequency (f<sub>sw</sub>), and the I<sub>LED</sub> dimming frequency in indirect PWM dimming mode and mixed dimming mode.

| Bits | Access | Bit Name | Default | Description  |
|------|--------|----------|---------|--|
| 7:6  | R/W    | SRSW     | 2'b10   | Selects the switching slew rate.<br>2'b00: 1 driver<br>2'b01: 2 drivers<br>2'b10: 3 drivers<br>2'b11: Reserved |
| 5:4  | R/W    | FSW      | 2'b10   | Selects the boost f <sub>sw</sub> .<br>2'b00: 312kHz<br>2'b01: 625kHz<br>2'b10: 1250kHz<br>2'b11: Reserved     |
| 3:0  | R      | RESERVED | N/A     | Reserved.  |

**FSS\_LEDS (0Bh)**

The FSS\_LEDS command sets the modulation frequency and the frequency spread range for the frequency spread spectrum (FSS) function. It can also set the protection threshold for LED short protection and the compensation saturation time for LEDx pin short to GND protection.

| Bits | Access | Bit Name | Default | Description  |
|------|--------|----------|---------|--|
| 7    | R      | RESERVED | N/A     | Reserved.  |
| 6:5  | R/W    | FSPMF    | 2'b11   | Selects the FSS modulation frequency.<br>2'b00: 1/100 of f <sub>sw</sub><br>2'b01: 1/150 of f <sub>sw</sub><br>2'b10: 1/200 of f <sub>sw</sub><br>2'b11: Disables the FSS function |
| 4    | R/W    | FSPR     | 1'b0    | Selects the FSS range.<br>1'b0: 1/10 of f <sub>sw</sub><br>1'b1: 1/16 of f <sub>sw</sub>   |
| 3:2  | R/W    | LEDS     | 2'b01   | Selects the LED short protection threshold.<br>2'b00: 2V<br>2'b01: 5V<br>2'b10: 7V<br>2'b11: 10V   |
| 1    | R/W    | TCOMP    | 1'b1    | Selects the compensation saturated time for short LEDx to GND protection.<br>1'b0: 20ms<br>1'b1: 40ms  |
| 0    | R      | RESERVED | N/A     | Reserved.  |

**VOUT\_SET (0Eh)**

The VOUT\_SET command sets V<sub>OUT</sub> of the boost circuit. In adaptive mode, this command sets the initial V<sub>OUT</sub> when the boost circuit starts up, and the final V<sub>OUT</sub> is adjusted to a proper level adaptively. In manual mode, this command sets the final V<sub>OUT</sub> for the LED strings.

| Bits | Access | Bit Name | Default | Description  |
|------|--------|----------|---------|--|
| 7:0  | R/W    | VO       | 8'h32   | Sets V <sub>OUT</sub> .<br>8'h00 = 16V, 8'h01 = 16.106V,..., 8'hFF = 43V.<br>The step is 0.106V. Default = 21.25V. |

**ID (1Dh)**

The ID command indicates the device's ID.

| Bits | Access | Bit Name | Default | Description           |
|------|--------|----------|---------|-----------------------|
| 7:0  | R      | ID       | 8'h11   | Sets the device's ID. |

**FAULT (1Fh)**

The FAULT command indicates the status of each type of fault.

| Bits | Access | Bit Name | Default | Description   |
|------|--------|----------|---------|---|
| 7    | R      | RESERVED | N/A     | Reserved.   |
| 6    | R      | FT_UVLO  | 1'b0    | Indicates the UVLO fault indicator.<br>1'b0: There is no fault<br>1'b1: There is a fault<br><br>If a fault occurs, the fault bit remains set to 1 until readback or the power becomes reset.                |
| 5    | R      | FT_LEDG  | 1'b0    | Indicates the LEDx short to GND protection fault.<br>1'b0: There is no fault<br>1'b1: There is a fault<br><br>If a fault occurs, the fault bit remains set to 1 until readback or the power becomes reset.  |
| 4    | R      | FT_OTP   | 1'b0    | Indicates the over-temperature protection fault.<br>1'b0: There is no fault<br>1'b1: There is a fault<br><br>If a fault occurs, the fault bit remains set to 1 until readback or the power becomes reset.   |
| 3    | R      | FT_OCP   | 1'b0    | Indicates the over-current protection (OCP) fault.<br>1'b0: There is no fault<br>1'b1: There is a fault<br><br>If a fault occurs, the fault bit remains set to 1 until readback or the power becomes reset. |
| 2    | R      | FT_OVP   | 1'b0    | Indicates the OVP fault indication.<br>1'b0: There is no fault<br>1'b1: There is a fault<br><br>If a fault occurs, the fault bit remains set to 1 until readback or the power becomes reset.                |
| 1    | R      | FT_LEDO  | 1'b0    | Indicates the LED open protection fault.<br>1'b0: There is no fault<br>1'b1: There is a fault<br><br>If a fault occurs, the fault bit remains set to 1 until readback or the power becomes reset.           |
| 0    | R      | FT_LEDS  | 1'b0    | Indicates the LED short protection fault.<br>1'b0: There is no fault<br>1'b1: There is a fault<br><br>If a fault occurs, the fault bit remains set to 1 until readback or the power becomes reset.          |

## APPLICATION INFORMATION

### Setting the Full-Scale LED Current

The full-scale LED current ( $I_{SET}$ ) can be configured by the maximum LED current ( $I_{MAX}$ ) (set via IMAX (07h, bits[6:4])) and the ISET resistor ( $R_{ISET}$ ) when ISET\_EN (08h, bit[2]) = 1b.  $I_{SET}$  can be calculated with Equation (1):

$$I_{SET} \text{ (mA)} = \frac{40}{R_{ISET} \text{ (k}\Omega)} \times I_{MAX} \quad (1)$$

For example,  $I_{MAX} = 20\text{mA}$  (IMAX = 011b) and  $R_{ISET} = 40\text{k}\Omega$ , then  $I_{SET}$  is 20mA.

When ISET\_EN = 0b,  $R_{ISET}$  is invalid, and  $I_{SET}$  is only configured via IMAX (07h, bits[6:4]).

### Selecting the Input Capacitor

The input capacitor ( $C_{IN}$ ) reduces the surge current drawn from the input supply and the switching noise from the device. The  $C_{IN}$  impedance at  $f_{SW}$  should be below the input source impedance to prevent the high-frequency switching current from passing through to the input. Use ceramic capacitors with X5R or X7R dielectrics for their low-ESR and small temperature coefficients. For most applications, a 10 $\mu\text{F}$  ceramic capacitor is sufficient.

### Selecting the Inductor

The MP3314A requires an inductor to supply a higher  $V_{OUT}$  while being driven by  $V_{IN}$ . A larger-value inductor results in reduced ripple current and peak inductor current, as well as reduced stress on the internal N-channel MOSFET. However, the larger-value inductor also has a larger physical size, higher series resistance, and lower saturation current.

Choose an inductor that does not saturate under the worst-case load conditions. Select the inductance to ensure that the boost converter works in discontinuous conduction mode (DCM) to avoid subharmonic oscillations.

The required inductance can be calculated with Equation (2):

$$L \leq \frac{V_{IN\_MIN} \times (V_{OUT} - V_{IN\_MIN})}{V_{OUT} \times f_{SW} \times I_{CL}} \quad (2)$$

Where  $V_{IN\_MIN}$  and  $V_{OUT}$  are the minimum input voltage and output voltages,  $f_{SW}$  is the switching frequency, and  $I_{CL}$  is the cycle-by-cycle current limit.

With the given inductance, the inductor DC current rating exceeds the maximum input peak inductor current by a minimum of 40% for most applications. The inductor's DC resistance must be minimized to achieve higher efficiency.

### Selecting the Output Capacitor

The output capacitor ( $C_{OUT}$ ) keeps the  $V_{OUT}$  ripple small and ensures feedback loop stability. The  $C_{OUT}$  impedance must be low at  $f_{SW}$ . Ceramic capacitors with X7R dielectrics are recommended for their low-ESR characteristics. For VR applications, a large electrolytic  $C_{OUT}$  is required to maintain  $V_{OUT}$  and the output power. The required electrolytic capacitance can be calculated with Equation (3):

$$\left\{ \begin{array}{l} C \geq \frac{2 \times D_{PWM\_MAX} \times (V_{OUT} \times I_{OUT} - V_{IN\_MIN} \times I_{IN})}{f_{PWM\_MIN} \times [V_{OUT}^2 - (V_{OUT} - \Delta V)^2]} \\ C \leq \frac{2 \times (1 - D_{PWM\_MAX}) \times V_{IN\_MIN} \times I_{IN}}{f_{PWM\_MIN} \times [V_{OUT}^2 - (V_{OUT} - \Delta V)^2]} \end{array} \right. \quad (3)$$

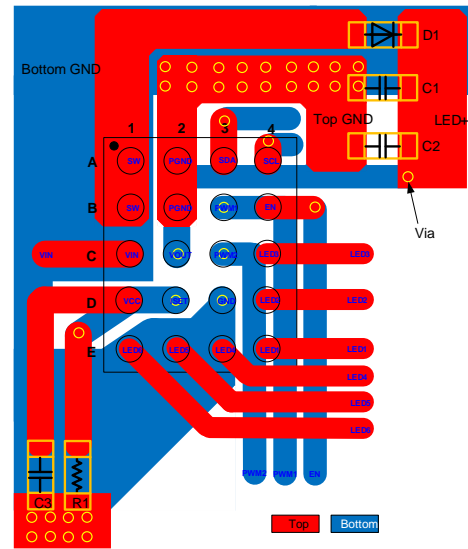
$$I_{IN} = \frac{I_{CL}^2 \times L \times f_{SW} \times V_{OUT}}{2 \times V_{IN\_MIN} \times (V_{OUT} - V_{IN\_MIN})}$$

Where  $D_{PWM\_MAX}$  and  $f_{PWM\_MIN}$  are the maximum duty and the minimum frequency of the PWM1 and PWM2 input signals in application,  $I_{OUT}$  is the total LED current when PWM1 and PWM2 are both on,  $I_{IN}$  is the input current,  $\Delta V$  is the maximum voltage drop of the electrolytic capacitor when PWM1 and PWM2 are both on.

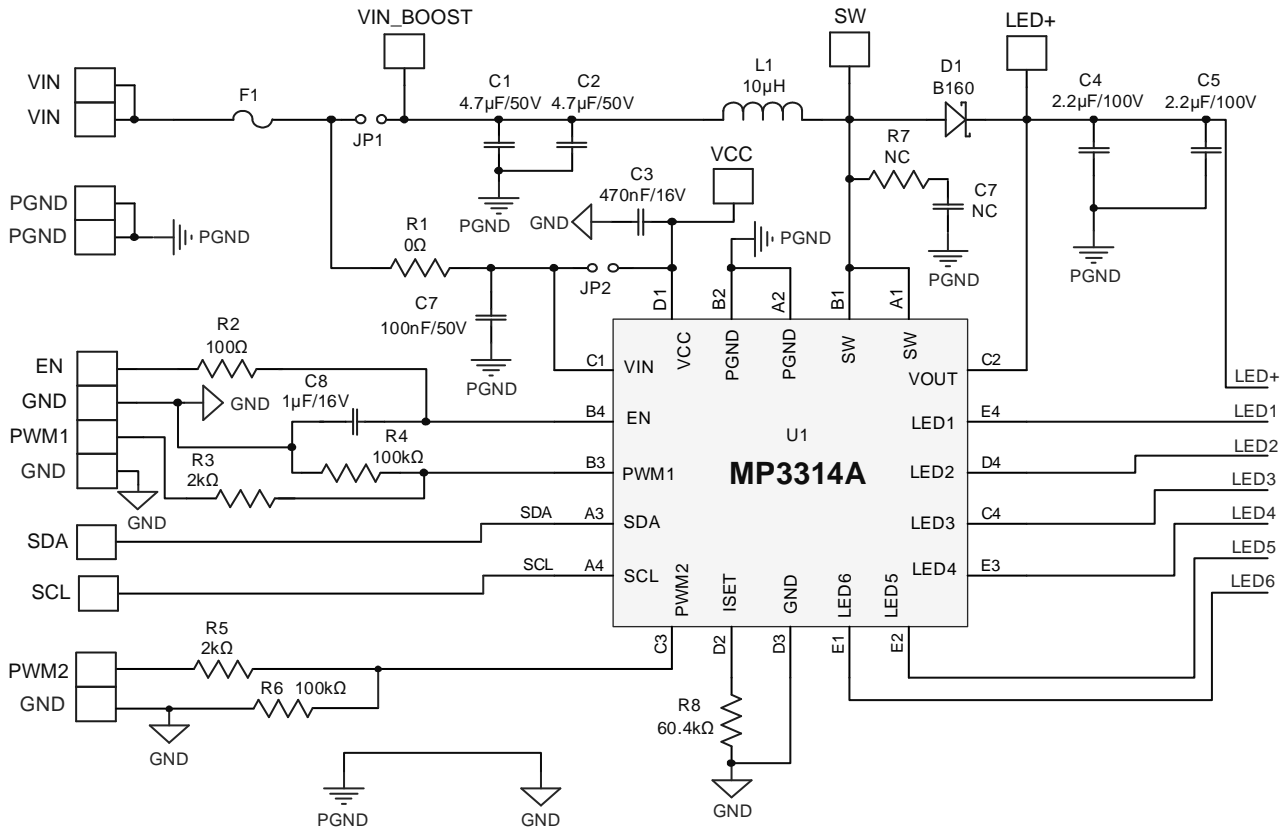
### PCB Layout Guidelines

Efficient PCB layout and placement of the high-frequency switching path is critical to prevent noise and electromagnetic interference. Refer to Figure 5 and follow the guidelines below:

1. All logic signals must be referred to AGND.
2. Externally connect PGND to AGND.
3. Route PGND away from the logic signals.
4. Keep the loop between the SW and PGND pins, output diode (D1), and output capacitor (C1 and C2) as short as possible due to the high-frequency pulse current.

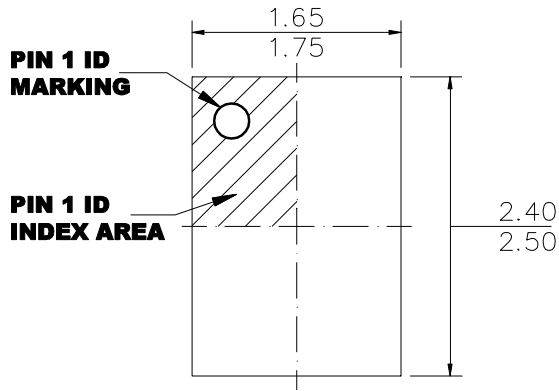


**Figure 5: Recommended PCB Layout**

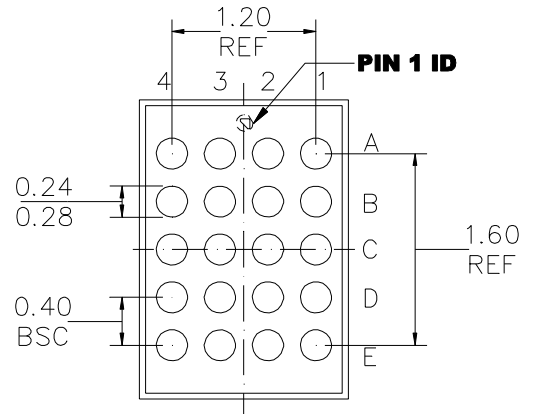
**TYPICAL APPLICATION CIRCUIT**

**Figure 6: Typical Application Circuit**

**PACKAGE INFORMATION**

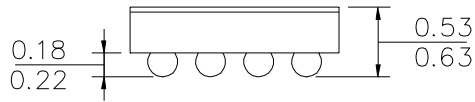
**WLCSP-20 (1.7mmx2.45mm)**



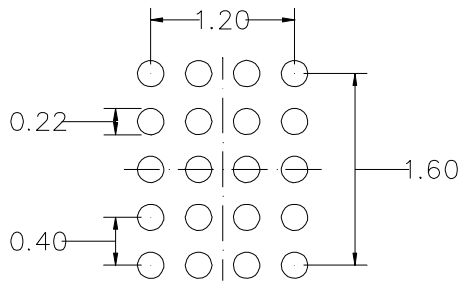
**TOP VIEW**



**BOTTOM VIEW**



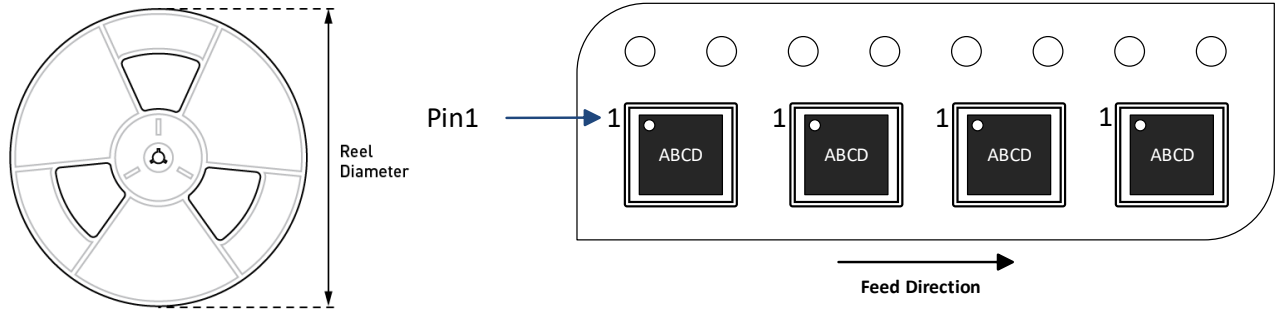
**SIDE VIEW**



**RECOMMENDED LAND PATTERN**

**NOTE:**

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.
- 2) BALL COPLANARITY SHALL BE 0.05 MILLIMETER MAX.
- 3) JEDEC REFERENCE IS MO-211.
- 4) DRAWING IS NOT TO SCALE.

**CARRIER INFORMATION**


| Part Number | Package Description            | Quantity/ Reel | Quantity/ Tube | Quantity/ Tray | Reel Diameter | Carrier Tape Width | Carrier Tape Pitch |
|-------------|--------------------------------|----------------|----------------|----------------|---------------|--------------------|--------------------|
| MP3314AGC-Z | WLCSP-20<br>(1.7mmx<br>2.45mm) | 3000           | N/A            | N/A            | 7in           | 8mm                | 4mm                |

## REVISION HISTORY

| Revision # | Revision Date | Description     | Pages Updated |
|------------|---------------|-----------------|---------------|
| 1.0        | 9/26/2024     | Initial Release | -             |

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